

Study of the mechanical and electrical characteristics of the synchronous motor with varying resistive torque

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Abstract. The paper presents the mechanical and electrical characteristics of the synchronous motor for imposed moment variations at the shaft. The test setup is presented, used to determine the electrical and mechanical characteristics of the synchronous motor. Modelling the resistive torque allows the loading with different torsion vibrations. It is presented the used experimental workbench in order to determine the mechanical and electrical characteristics of synchronous motors in such conditions. The engine torque model allows the shaft to be loaded with variable resistive torque values generated by an electromechanical brake. The characteristics presented show the mechanical characteristic of the synchronous motor. Mechanical rotation speed characteristics are presented based on the variation of the resistive torque for 40 seconds, taking note of the value of the resistance when the motor exits synchronism. The determination of these characteristics are made based on the variation of the excitation current applied to the rotor winding of the synchronous motor.

1. Introduction

The synchronous machine is reversible from an energetic and point of view.

The inducing magnetic-field for synchronous machines can be generated depending on the machine's construction. The frequency of the induced voltage is dependent on the rotational speed of the rotor and the number of poles of the machine. The current generated by the windings has the same frequency as the induced voltage. The magnetic field induced by symmetrical poly-phase machines is circular and has a rotational speed related to this frequency.

Between the two magnetic fields, inducing and induced, in relative resting state, there is an interaction specific to the stationary regime. Depending on the frequency, the rotational speed of the rotor is equal to the rotation speed of the rotating magnetic field generating the synchronicity state of the synchronous machine. The excitation current in the inductor winding is generated by the continuous current supplying this winding [1].

Depending on its location, the excitation winding in the machine can generate certain powers. Inner-pole machines where the excitation winding is located in the rotor generate significant power. Outer-pole machines where the excitation winding is located in the stator generate powers up to 20 kVA [2].

Cylindrical poles are used for rotational speeds of 1500 rpm and 3000 rpm at a frequency of 50Hz. Salient poles are used for rotational speeds of up to 1500 rpm. The shape of the rotor, dependent on the type of poles, may define the use of motors for different rotational speeds. The synchronous machine has a great use as a generating machine. If a synchronous machine is driven by a steam

turbine, the synchronous generator is a turbo-generator with rotational speeds of over 1000 rpm. If the synchronous machine is of the hydraulic type, the synchronous generator is a hydro generator [1].

2. The synchronous motor

The synchronous machine has a rigid characteristic. The rotational speed does not depend on the load [3]. The engine keeps its rotational speed constant. The slope of the characteristic is linear and is given by expression [4].

$$M = \frac{d\Omega}{dM} \quad (1)$$

3. Mechanical and electrical characteristics of the synchronous motor

The choice of the type of engine depending on the application is determined by the specific power and rotational speed of the application, its rational use, the possibility of speed adjustment etc., require the study of the mechanical and electric characteristics of the motor. Each type of motor has a multitude of characteristics [5].

For determining the mechanical and electrical characteristics of the motors an experimental test setup is used comprised of a tripolar switch with two positions, a power supply with thermal overload protection, a digital/analog multimeter, an adjustable excitation autotransformer, a controller and a brake servomotor and a synchronous machine.

The excitation winding is fed through an autotransformer. This voltage, as well as the three-phase supply voltage of stator winding, connected in the star configuration is monitored by two digital multimeters. In the Activeservo dedicated software, the controller monitors and induces braking at predefined moments of the engine torque by means of a servomotor [5].

4. Torque modelling for characteristics determination

The operation of the synchronous motor is determined by the variations in torque. The test program enables the experimental-setup to generate those application-specific resistive torques. The most important part of this system is the controller which, through the ActiveServo software, transmits the servomotor predefined torques for testing [6].

The Active Servo software is a tool for monitoring and registering the machine's characteristic in order to determine the static and dynamic operating points [5].

The controller generates resistive torques imposed on the studied characteristic.

The servomotor is in close-connection with the controller and is a monitoring and braking system. The servomotor has multiple characteristics, which are related to the speed regulation within very wide limits, the mechanical characteristics generated are linear, is protected against self-start and a high overload capacity [6].

5. Mechanical and electrical characteristics over time for variable torque values.

For the experimental determinations performed to study the characteristics, a synchronous motor with the following characteristics was used: $P_n = 0.27\text{kW}$, $I_n = 1.5\text{A}$, $f = 50\text{Hz}$, $n = 1500\text{rpm}$, $U_{err} = 20\text{Vcc}$; $I_{err} = 4\text{A}$. The excitation source generated a voltage in steps of 0-20 V_{cc} at imposed excitation current values of 0.5A, 1A, 2A, 3A.

For the studied synchronous motor we will observe the time dependence of the following quantities: The current of the rotor circuit, I [A]; Mechanical power at the shaft P_2 [W]; Motor torque M [Nm] and Speed n [rpm].

The engine is driven at synchronism speed for 6 excitation current values, between 0.5 and 3A, in 0.5A steps. Via programming we have imposed a torque characteristic at which for 100 seconds we plotted the torque so that for variable values forced from 0 to the maximum synchronicity value we reduced and alternated with mechanical shocks up to the return value to the nominal values.

5.1. For $I_{err}=0.5\text{A}$

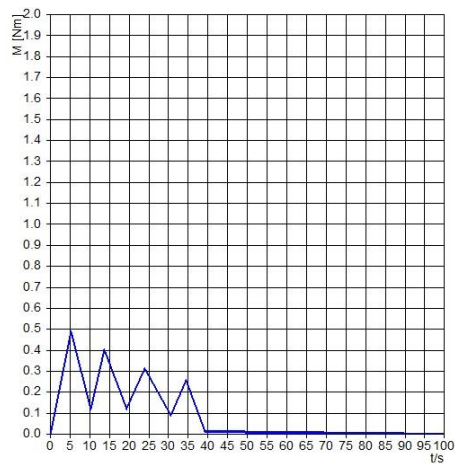


Figure 1. Imposed torque characteristic for $I_{err}=0.5A$

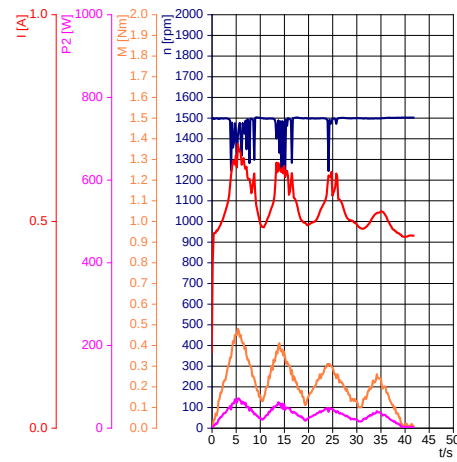


Figure 2. Mechanical and electrical characteristics for time-varying torques for an excitation current of $I_{err}=0.5A$

By analyzing the previous chart, it is noticed that the engine has a constant speed at increasing torque values, but tends to de-synchronize at higher torque values, however does not exit synchronism. Speed returns to a nominal value along with decreasing torque values. The electrical current in the stator circuit maintains the required torque curve, as well as the mechanical power at the motor shaft.

5.2. For $I_{err} = 1A$

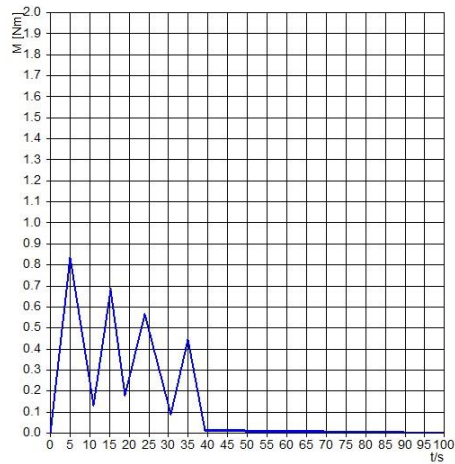


Figure 3. Imposed torque characteristic for $I_{err} = 1A$

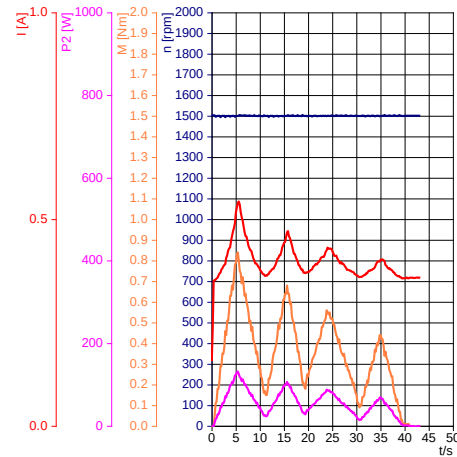


Figure 4. Mechanical and electrical characteristics for time-varying torques for an excitation current of $I_{err}=1A$

By analyzing the previous graph, it is noticed that the speed is kept constant at alternating variations of torque, if the torque increase or decrease is done linearly increasing within 5s limit. The electric current in the stator circuit maintains the imposed torque curve, as well as the mechanical power at the engine shaft.

5.3. For $I_{err} = 1,5A$

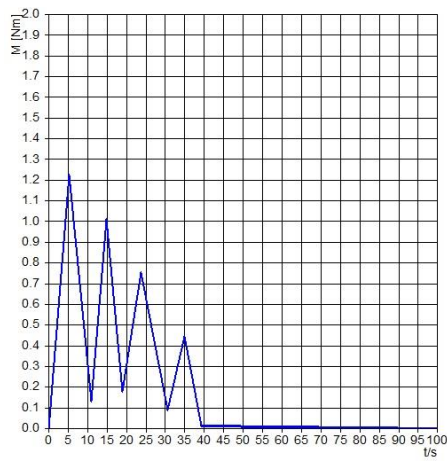


Figure 5. Imposed torque characteristic for $I_{err}=1.5$ A

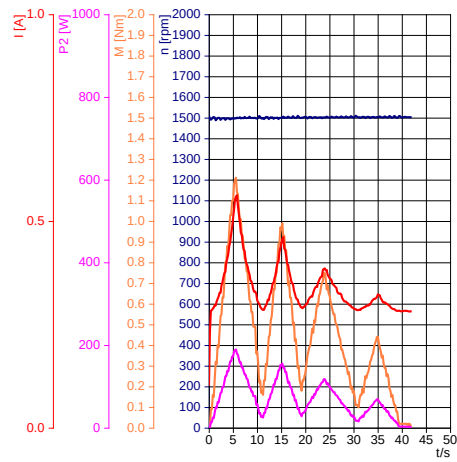


Figure 6. Mechanical and electrical characteristics for time-varying torques for an excitation current of $I_{err}=1.5$ A

When analyzing the torque variation, we increased the maximum torque to 1.2Nm so that it came close to the exit-value of synchronism, we increased the other torque variables, but making sure the studied allure is kept.

From the previous graph, it is noticed that the speed is kept constant at alternating variations of torque, if the torque increase or decrease is done linearly increasing within 5s limit. The electric current in the stator circuit maintains the imposed torque curve, as well as the mechanical power at the engine shaft.

5.4. For $I_{err}=2$ A

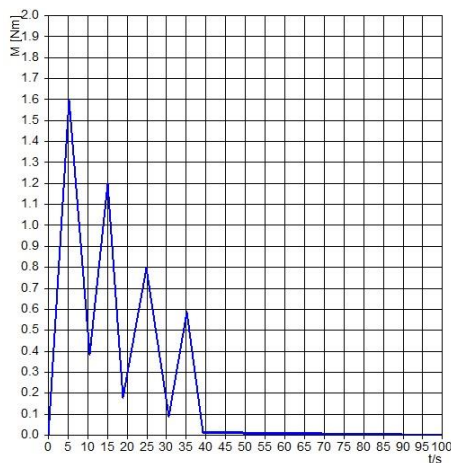


Figure 7. Imposed torque characteristic for $I_{err}=2$ A

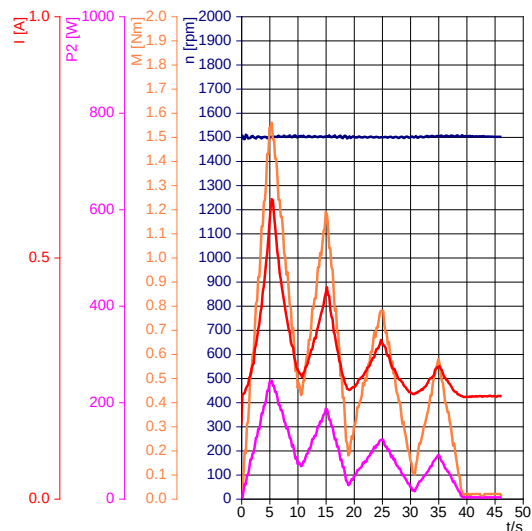


Figure 8. Mechanical and electrical characteristics for time-varying torques for an excitation current of $I_{err}=2$ A

When analyzing the torque variation, we increased the maximum torque to 1.6Nm so that it came close to the exit-value of synchronism, we increased the other torque variables, but making sure the studied allure is kept.

From the previous graph, it is noticed that the speed is kept constant at alternating variations of torque, if the torque increase or decrease is done linearly increasing within 5s limit. Also, when increasing the excitation current, the speed variations are flattened.

The electric current in the stator circuit maintains the imposed torque curve, as well as the mechanical power at the engine shaft. From observation, if we increase the excitation current value, the engine resists larger torque shocks

5.5. For $I_{err} = 2.5A$

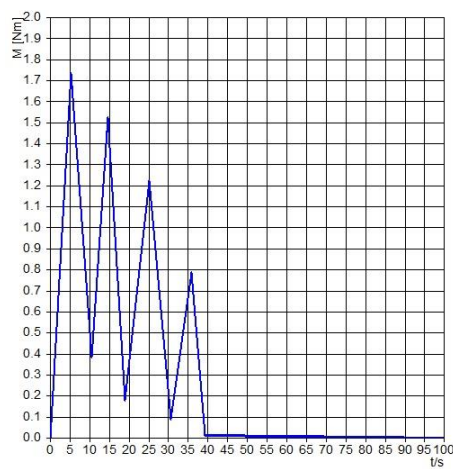


Figure 9. Imposed torque characteristic for $I_{err} = 2.5 A$

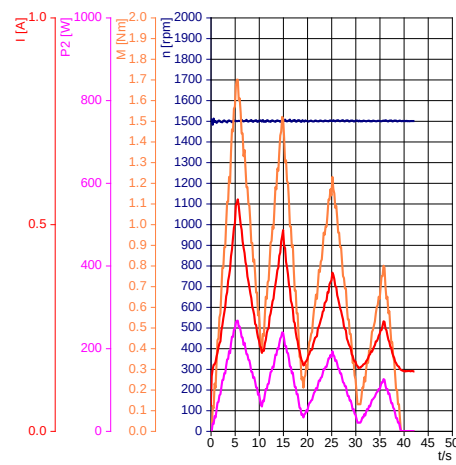


Figure 10. Mechanical and electrical characteristics for time-varying torques for an excitation current of $I_{err} = 2.5 A$

When analyzing the torque variation, we increased the maximum torque to 1.75Nm so that it came close to the exit-value of synchronism, we increased the other torque variables, but making sure the studied allure is kept.

From the previous graph, it is noticed that the speed is kept constant at alternating variations of torque, if the torque increase or decrease is done linearly increasing within 5s limit. Also, when increasing the excitation current, the speed variations are flattened.

The electric current in the stator circuit maintains the imposed torque curve, as well as the mechanical power at the engine shaft.

5.6. For $I_{err} = 3A$

When analyzing the torque variation, we increased the maximum torque to 1.95Nm so that it came close to the exit-value of synchronism, we increased the other torque variables, but making sure the studied allure is kept.

From the graph presented in figure 12, it is noticed that the speed is kept constant at alternating variations of torque, if the torque increase or decrease is done linearly increasing within 5s limit. Also, when increasing the excitation current, the speed variations are flattened.

The electric current in the stator circuit maintains the imposed torque curve, as well as the mechanical power at the engine shaft.

From observation, if we increase the excitation current value, the engine resists larger torque shocks

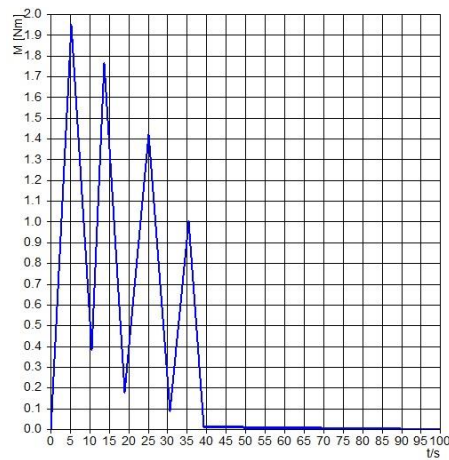


Figure 11. Imposed torque characteristic for $I_{err} = 3$ A

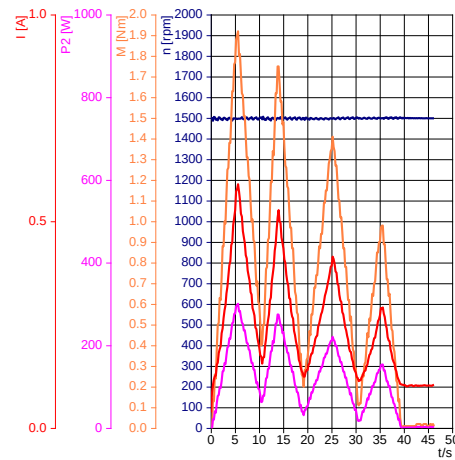


Figure 12. Mechanical and electrical characteristics for time-varying torques for an excitation current of $I_{err} = 3$ A

6. Conclusions

From the comparative analysis of the graphs, it is observed the influence of the excitation current on the synchronous motor when it is subjected to different values of resistive torque, which comes close to the maximum torque of the motor near the moment of de-synchronization.

Thus, if the synchronous motor tends to de-synchronize at a 0.5A excitation current, we notice that this does not happen and the engine returns to synchronous speed. If we increase the excitation current value, the engine resists larger torque shocks but does not de-synchronize and maintains its speed relatively constant within an acceptable range of variation.

The value of the excitation current is determined to be decisive and its variability influences keeping the engine's speed constant with varying resistive torque at the shaft.

7. References

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